

TECHNICAL SPECIFICATION FOR ULTRASONIC INSPECTION

0 PREAMBLE

The ultrasonic examination of cast steel parts allows the detection of possible internal defects and to estimate as far as possible, their nature, their dimensions and their position in the section under examination.

The inspection method described in this technical specification is based on the reflection of ultrasonic waves produced by a defect or the opposite surface of the part and is visualized by an echo on the screen of the apparatus (method of echo pulse ultrasonic testing).

The operator manually shifts the probe by applying it on the surface to be inspected which is covered with couplant (contact technique).

The choice of the probe depends on various parameters (geometric shape of the parts, acoustic permeability to ultrasound, type of defects sought).

For this research, the types of probes that are available are:

- a) Standard longitudinal wave probes.
- b) Standard transverse wave angle probes.
- c) Probes with separate transmitter and receiver (SE type) for longitudinal wave or angle probes for transverse wave.

0.1 PART 1 : LONGITUDINAL WAVES EXAMINATION

This ultrasonic examination using normal longitudinal wave probes with flexible membrane is applied in most cases to identify and locate defects in steel castings.

0.2 PART 2 : TRANSVERSE WAVES EXAMINATION

This ultrasonic examination, which uses transverse wave angle probes is more specific to control areas assembled or repaired by welding, for characterisation of indications and for controls of weld ends...

The examination must be specified in the Quality Sheet or in the technical specification of the Designer (probe used, areas to examine, acceptance criteria) and must be defined during the call for tender and placement of the order.

In the absence of specification, the founder will use the technique described in part 1.

Note :

- *Ultrasonic inspection has its limitation and can only give an indication of the type of defect revealed by the ultrasonics.*
- *Ultrasonic inspection and radiographic inspection do not supply indications which are directly comparable.*
- *For the ultrasonic inspection of the cast steel parts of austenitic or austenoferritic (Duplex) steels, special measures must be specified by the parties involved.*
- *The application of longitudinal wave angle probes is not considered in this specification.*

PART 1

LONGITUDINAL WAVES EXAMINATION

1.1 OBJETIVE AND FIELD OF APPLICATION

This specification outlines the measures to be implemented for ultrasonic inspection of ferritic or martensitic steel castings, whose thickness varies between 10 and 600 mm. For parts under or over these limits, the control method must be defined by the parties involved.

Its purpose is to detect possible internal defects in the parts, to designate the indications and to define the acceptance criteria.

It applies to the pulse echo ultrasonic testing with longitudinal waves (normal longitudinal wave probe).

1.2 METHODS USED

The methods described in this specification are :

- either plot a «Distance Amplitude Curve» (**DAC**) from the deflection of longitudinal waves obtained on flat bottom holes on reference blocks.
- or use the existing reference diagrams (**AVG** method).

The choice of either of these methods for inspection of parts will be specified in the Quality Sheet.

The normal longitudinal probe is manually displaced on the surface of the part to be examined. Internal discontinuities resulting in the appearance of a pulse echo and/or the decrease of the back echo when this back echo can be obtained in an area having parallel surfaces, are analysed while considering size, amplitude, position and the nature of the defect. The results obtained are compared to the criteria of acceptability.

1.3 ULTRASONIC INSPECTION MATERIAL

1.3.1 APPARATUS

Characteristic of the apparatus:

- The pulse generator will allow the performance of tests at frequencies varying between 1 and 5 MHz using standard probes or separate transmitter/receiver type probes.
- Visualization is of type A.
- The apparatus will be equipped with a calibrated amplification control, graduated in dB, adjusted by increments of at least 2 dB.

The verified characteristics are :

- The linearity of the amplification: The difference will be less than ± 2 dB over the entire scale used.
- The time base linearity or the horizontal linearity: The difference should be less than 2% of the measuring range.
- Vertical linearity: In the absence of a threshold the difference should not exceed 5% of the height of the screen.

All these verifications should be made for each generator:

- Upon its purchase
- After repair
- At least once a year.

A calibration report is produced. Every apparatus must have a label indicating the date of calibration validity.

1.3.2 PROBES

The nominal frequency of the probes and the dimensions of the piezo-electric chips are chosen subject to the nature, the dimensions and the geometry of the part to be examined and the type of defect sought. The recommended frequency is 2 MHz.

One can use either of the following two longitudinal wave probes:

- Standard longitudinal wave probe

These probes are often used with a flexible protective membrane. The dead zone must be as short as possible.

- Separate transmitter and receiver probes (twin probe)

These are recommended for the detection of surface defects and defects in thin parts ≤ 50 mm. The converging area of these probes with separate transmitter and receiver must be adapted to the inspection to be performed.

The methods of use are specified in the Quality Sheet. In the absence of specific indications, a standard longitudinal wave probe will be used. ♦

1.3.3 OPERATIONS TO PERFORM DAILY ON THE APPARATUS AND AT EVERY CHANGE OF SHIFT

- Verification of physical condition and external appearance of the apparatus (pulse generator, probe, cable).
- Quick verification of the calibrated amplifier.
- Verification of sensitivity and of the resolution power of each probe used.

a) Sensitivity

A plastic insert from the international calibration block IIW A2 will be used.

The number of visible echoes on the oscillogram, set at the maximum gain if necessary, should not be less than the number indicated on table 1 for the frequency range chosen with a standard longitudinal wave probe of 20 to 26 mm in diameter.

Table 1
Minimal number of echoes

Frequency range MHz	Minimal number of echoes
0,5 to 1,3	5
> 1,3 to 1,8	4
>1,8 to 2,6 (*)	3
2,7 to 5,0	2

(*) Recommended range

b) Resolution power

The depth resolution must be assessed for the complete control apparatus (apparatus-cable-probe) by measuring the width of the first back echo using the 25 mm section of the basic steel calibration block IIW A2.

The amplitude of the echo must be set at 80 to 100% of the total height of the screen and the width of the echo must be measured in mm of steel at a value of 10% of the height of the echo. Table 2 gives the characteristic values:

Table 2
Characteristic values

Frequency MHz	Width of the echo longitudinal waves mm
1	15
2 or 2,25	9
4	5
5	4

1.3.4 COUPLANTS

May be used as couplants:

- Couplant pastes
- Oils
- Greases
- Cellulose glues diluted with water

The efficiency of the couplant used will be verified by obtaining one or several stable back echoes on parallel surface areas. This same couplant should be used for any adjustment and for all subsequent inspection operations.

The Designer may specify in the Quality Sheet the particular type of couplant to use.

1.3.5 REFERENCE BLOCKS

The reference block or blocks are used to establish the distance amplitude curve (DAC). These blocks are made of cast steel and present the acoustic characteristics which are similar to the material to be inspected.

The difference of the fading of the ultrasonic signal between the reference block and the part to be inspected will be examined (see § 1.4.5).

Reflectors are flat bottomed holes of 6 mm (+ 0.4/-0) drilled perpendicular to the surface to be inspected. A set of reference blocks must include at least 4 flat bottomed holes chosen in a scale of 25-50-75-150-250 mm. For inspection of parts of more than 380 mm, one or several extra blocks of defined thickness relative to the order are added to the basic set. The dimensions of the reference blocks will be based on the ASTM A 609 standard or other equivalent standards.

Each block must be identified permanently on the side through its identification and steel grade.

1.4 INSPECTION CONDITIONS

1.4.1 STAGE OF INSPECTION

Ultrasonic inspection is always carried out after quality heat treatment.

1.4.2 AREAS TO BE INSPECTED

The area or areas to be inspected and the extent of inspections are specified in the Quality Sheet..

- **100% ultrasonic testing** symbolized by an X on the Quality Sheet in the space corresponding to the area in question. The probe is shifted along parallel lines with recovering so as to examine the entire area successively.
- **Spot check inspection** symbolized by QL, QP or SL.

QL followed by a number: The probe is shifted along the lines of a squared or chequered area; the number following the symbol indicate the squaring pitch in mm.

QP followed by a number: The probe is placed successively over each intersection of lines as described above.

SL the probe is shifted along lines defined for each case.

For spot check inspections the following regulation will be applied :

- To avoid the application of the clause mentioned in § 4 of the «INTRODUCTION», the Designer is to define clearly, at the latest when passing an order, the exact location of the intersection of the lines. ♦
- If a defect is revealed its extent will be determined by inspecting the adjacent areas.
- The guarantee for a quality class specified being met on the entire area under examination depends on the squaring pitch and on the acceptance criteria required.

1.4.3 SURFACE PREPARATION

The Quality Sheet will prescribe the surface finish required for the inspection considering the acceptance criteria and the probes used.

The surfaces to be inspected on steel castings must be such that the couplants between the probe and the part will not have a significant influence on the sensitivity of the examination.

The surfaces should be without ondulations which could hinder the contact between the probe and the part.

The surfaces to be inspected must be free of rust, scales, weld spatter or other irregularities which would interfere with the transmission of ultrasonic waves or the movement of the probe.

The surface finish must at least correspond to samples 2S1 (for surfaces cleaned by sand or shot blasting) or 3 S2 (for ground surfaces) of the BNIF standard or subject to SCRATA A1 (for sanded surfaces) or H1 (for ground surfaces).

In general a surface finish corresponding to reference N10 (12.5.µm) as per ISO 1302 is acceptable. In case a separate transmitter receiver probe is used, the surface finish shouldn't be greater than 2S2 (Ra \leq 6.3 µm).

1.4.4 ADJUSTMENT OF THE SPEED OF SWEEP

By adjustment of the horizontal sweep the maximum distance between the transmission point of the pulse and the most distant possible echo should be obtained considering the adjustment limits of the apparatus. For calibrations only the distances between multiple echoes or between two echoes corresponding to distant reflectors of a known value may be used and not the distance between the pulse transmission and the first echo.

The way, the relative position of an echo is located on the screen permits to determine the depth of the corresponding reflector.

1.4.5 ADJUSTMENT OF AMPLIFICATION AND INTENSITY

1.4.5.1 Use of reference blocks: (DAC Method)

The adjustment of amplification and intensity is carried out on indications obtained from artificial reflectors (cylindrical holes with flat bottom of the reference blocks). These adjustments are carried out simultaneously, the amplification threshold being brought back to the minimum. During these adjustments the intensity must be maintained as low as possible, the height adjustment of the reference echoes is obtained only through the adjustment of amplification.

Correction of ultrasonic energy absorption.

To consider, to a certain extent, possible differences in surface finish and or absorption of ultrasonic waves between the casting under inspection and the reference block, the amplification can be modified as follows:

- Place the probe in an area of the casting which has parallel surfaces and whose thickness is equivalent to that of the block and whose surface finish and preferably whose internal structure are representative of the rest of the casting.
- Place successively the probe on the reference block (outside the area with artificial reflectors) and on the casting to be inspected.

Are to note :

- The two gains necessary to bring the back echo to a similar screen height.
- The difference in gain g_1 indicates the necessary increase in gain in correction of ultrasonic energy absorption.

The gain to be used for inspection corresponds to the gain used for establishing the distance amplitude curve, increased by g_1

In practice, this correction is made only if $g_1 > 2\text{dB}$

Adjustment based on indications obtained from artificial reflectors of the reference block

Two modes of adjustment may be used:

a) Distance amplitude curve (DAC)

The probe is placed in a way to obtain the maximum pulse echo on the reflector giving the strongest pulse and the adjustment is made so as to bring its amplitude to 80% approx of the height of the screen.

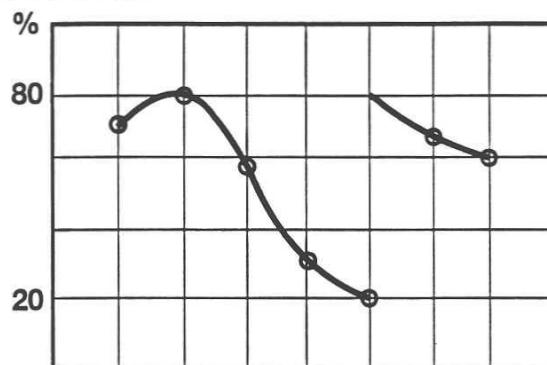
The maximum amplitude of the echoes received on each of the other reflectors is noted. The curve joining these points constitutes the distance amplitude curve. Except in the case of small thicknesses, this curve is plotted with a minimum of 3 points.

If the amplitude of the echo received on one reflector is less than 20% of the height of the screen, a fractionated distance amplitude curve will be plotted as indicated in figure 1.

A new adjustment is made so as to bring the amplitude of this echo to approximately 80% of the screen height.

b) If the apparatus used allows it, the distance amplitude curve may be replaced by a **diagram of the amplification values** necessary to bring the amplitude of the echoes on each reflector at the same height (approximately 80% of the screen height).

Figure 1 : Distance amplitude curve DAC



1.4.5.2 Use of existing reference diagrams : AVG Method (DGS method)

The AVG method is similar to the DAC method in so far as the objectives are concerned but it doesn't require artificial reflectors for plotting.

For most of the standard probes and for probes with separate transmitter / receiver, the manufacturers suggest using abacus type AVG screens which are placed on the apparatus screen (respectively electronic curves on digital equipment).

The abacus screen remains valid only if probes of the same type have similar characteristics. Acoustic absorption resulting from the material must not be neglected and the method of correction of ultrasonic energy absorption described in the DAC method is applicable. The adjustment of sensitivity is obtained from the reference echo which is brought to the screen of the ultrasonic apparatus to a given reference height.

1.4.6 FREQUENCY OF VERIFICATION OF THE ADJUSTMENTS

These adjustments must be made at the beginning of each inspection sequence and must be verified at the beginning and at the end of each shift and every time the operator suspects a drift in the installation.

Every verification is considered adequate if the drift noted stay smaller as ± 2 dB. Otherwise, the inspection must be carried out again as of the previous verification.

1.5 METHOD OF SEARCHING FOR DEFECTS

In all the areas that have to be 100% inspected, the operator must carry out a complete sweep making sure that there is a systematic recovering of at least 10% of the probe diameter.

The speed of shifting of the probe must be adapted to the examination conditions and must not exceed 150 mm/s.

The search for defects is made with an adjustment corresponding to as great a sensitivity as possible considering the electronic noise (grass) (approximately + 6dB).

INDICATIONS TO BE INVESTIGATED:

The indications to be investigated are:

- Intermediate echoes,
- Any back echo attenuation which is not explicable by the geometry of the casting.

Sometimes certain indications are impossible to interpret or may let presume the presence of flat defects as for example cracks. These indications will be considered to be «indications to be confirmed» (see § 1.8) in particular for areas in which significant repairs have been made.

1.6 CHARACTERIZATION OF INDICATIONS

1.6.1 LOCATION

The indications are localized relative to a known and defined system of marking.

1.6.2 DIMENSIONING OF INTERMEDIATE ECHOES OBTAINED

1.6.2.1 Dimensioning in amplitude from the distance amplitude curve (DAC) obtained over the flat bottomed holes.

- If the distance amplitude curve is used in conformity with § 1.4.5.1a the maximum amplitude of the indication is compared to the ordinate of the curve for the same sonic path and in the same conditions of adjustment used for its establishment. The extent of the defect is expressed in percentage of the distance amplitude curve.
- If the adjustment is made in conformity with the methods defined in § 1.4.5.1b, having determined the depth location of the indication, the adjustment is compared to the indication obtained for the artificial reflector which is the closest and whose amplitude is taken as a reference. The extent of defect is expressed as a percentage of the reference amplitude.

1.6.2.2 Dimensioning of amplification using the AVG method

The maximum amplitude obtained on the indication is compared to the AVG abacus curves for the same sonic path and in the original adjustment conditions. The degree of the indication is expressed in equivalent diameter

1.6.2.3 Dimensioning of indications

• Indications which can be measured in surface

The dimensioning involves demarcating the defects noted. The outline of the defect is defined by the positions of the centre of the probe corresponding to an amplitude of the echo equal to half of the maximum amplitude of the echo of the defect being inspected (the -6 dB method). This demarcation is made with the same probe or with a similar type probe in the same operating conditions used to detect the defect.

This demarcation requires the prior marking of the defects upon their detection. To demarcate the defect, the probe is shifted in all directions over the probed surface. The outline of the defect defines the surface S of this defect; the length of the defect is the largest dimension of the whole defect.

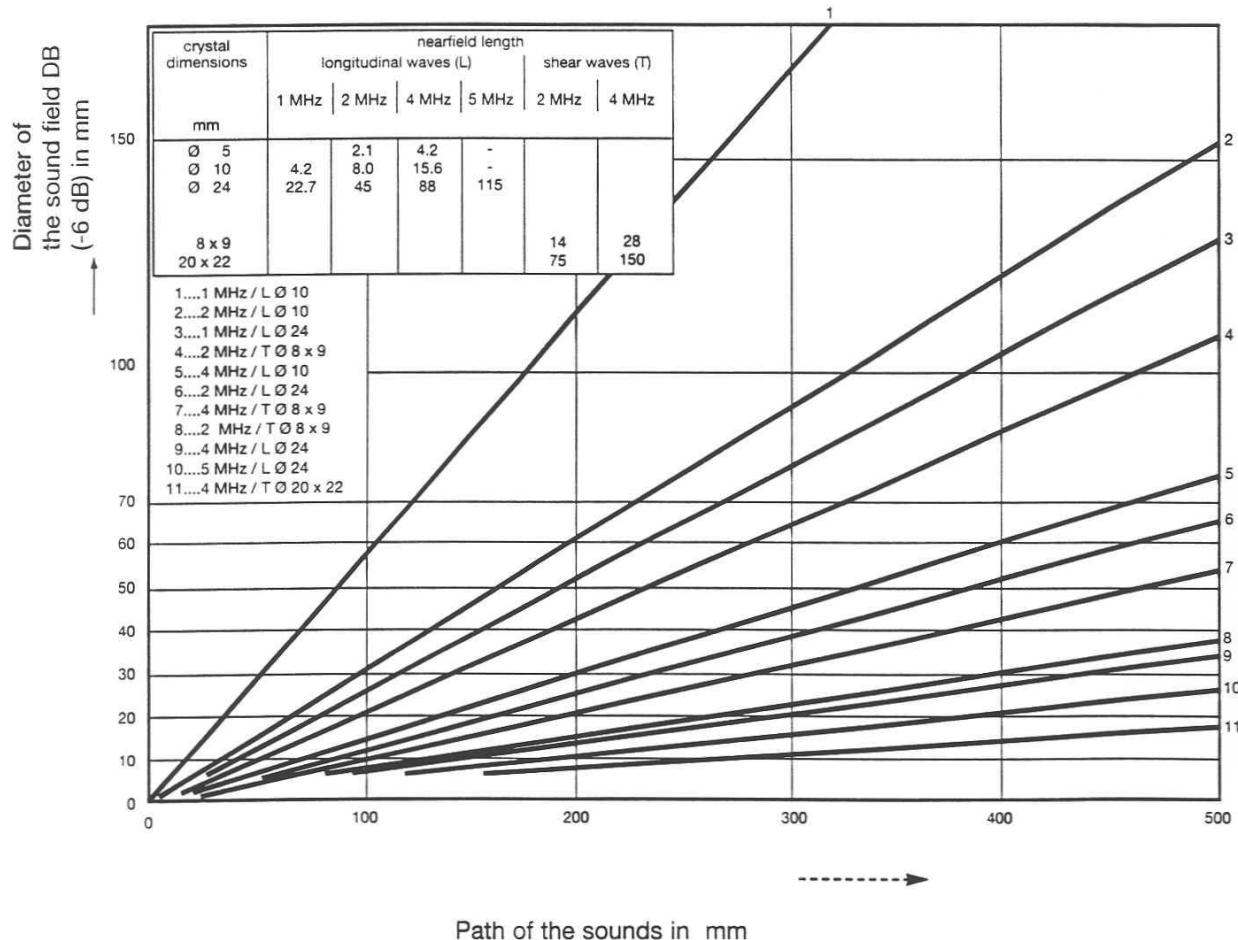
Note :

If the investigated surface is not relatively flat, determining the real surface of the defective area may require a sketch.

• **Indications which are not measurable in surface**

If the dimension of the indications is inferior or equal to the diameter of the ultrasonic beam, the indication is described as non measurable in surface. The following graph which is taken from the Euronorm CEN/TC 190 N224: 1993 (Figure 4) will be helpful .

The indications non measurable in surface will be evaluated as per §1.7«ACCEPTANCE CRITERIA».



Aproximate values of the length of the near field and the sonic beam diameter (-6dB) in the far field of the monocrystal standard probes based on the sound path (represented by curves 4,7,8 and 11 for angle probes). It is the smallest of the two axes of the elliptical sonic field.

1.6.3 DIMENSIONING RELATIVE TO THE DECREASE IN BACK ECHO

1.6.3.1 Dimensioning in amplitude

Any area in which a decrease in back echo is noted is characterized by the formula

$$\frac{\Delta F}{F_0} \quad \text{where } \Delta F = F_0 - F$$

F_0 = Height of the back echo in a sound area with parallel walls of similar thickness as the area to be examined.

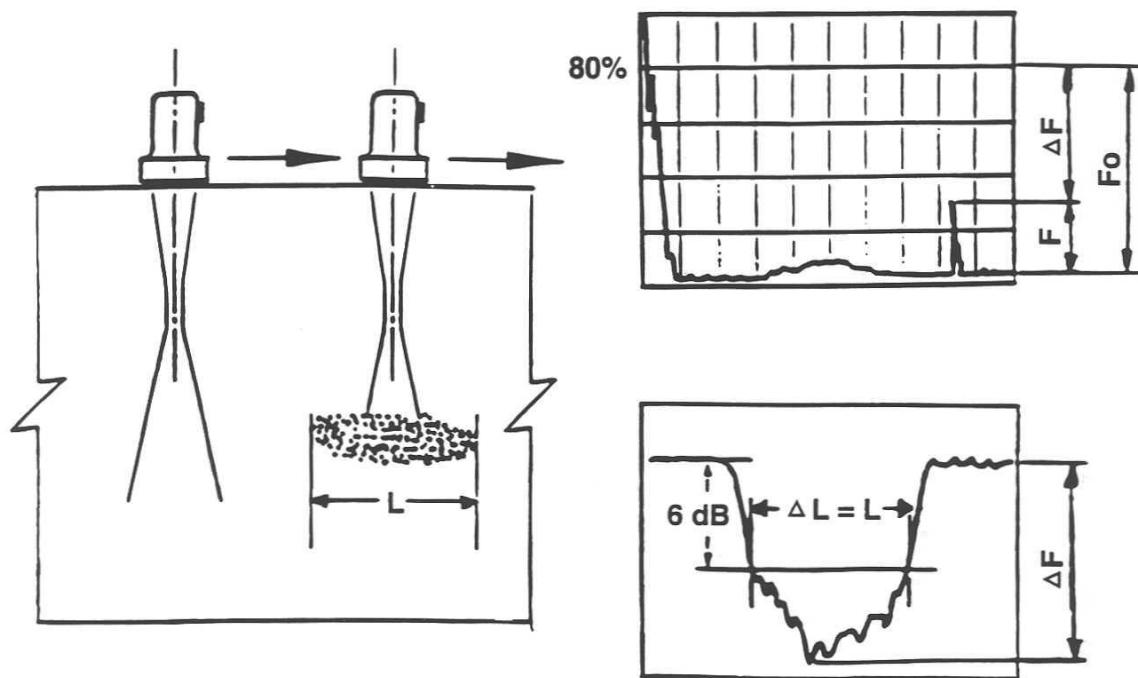
F = Height of the back echo in the examined area with parallel walls.

1.6.3.2 Dimensioning in geometry

F_0 is brought to a height of approximately 80% of the height of the screen.

The dimensioning involves the demarcation of the loss of back echo ΔF . The outline of the loss of the back echo is defined by the positions of the centre of the probe corresponding to ΔF maximum, minus 50% (see Figure 2). For each new position of the probe, the position of the beam axis is marked; the outline obtained by joining the positions of the beam axis defines the S surface of the defective area.

Figure 2 : Demarcation of the loss of back echo

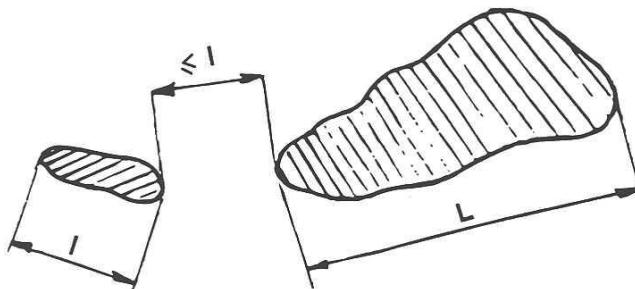


Dynamics of the loss of back wall-echo

1.6.4 CUMULATED INDICATIONS

Two neighbouring defects must be considered as constituting only one defect, of equal surface to the sum of both, if the distance which separates their outline is equal or less than the largest dimension of the smallest defect (figure 3).

Figure 3 : Cumulation of 2 neighbouring indications



1.7 ACCEPTANCE CRITERIA

The acceptance criteria may cover the height of the flow echo (defect echo), the equivalent diameter AVG, the attenuation of back echo, the number of non measurable indications, the surface of each elementary area, the total surface of the cumulated elementary areas.

Indications which exceed the acceptance criteria limits may be repaired or may «require confirmation»; the decision in this regard will be left to the Designer (see § 1.8).

Definitions

- D Height of the maximum echo on the defect after return to the calibrated amplification.
- R Height of the reference curve at the same depth.
- F Height of the back echo in the inspected area with parallel surfaces
- F₀ Height of the back echo on the sound area with parallel surfaces, of the same thickness as the area to be inspected.

$$\Delta F = F_0 - F$$

- S Surface of the elementary areas obtained by grouping «indications to be recorded» applying the method described in § 1.6.2.3. et 1.6.3.2.

() Numbers 1 to 9 between the parentheses indicate that one should refer to the legend at the end of §1.7, page 56.

Table 3 sets for both the DAC and AVG methods, the classes of quality 1 to 6 in order of decreasing severity, the notation threshold, the area of consideration of the indications and the attenuation of the back echo. Tables 4 and 5 set the maximum admissible indications.

In a same section, the Designer can determine several classes of severity. The repartition of the areas subject to the thickness of the part can be defined according to the legend (9). In this case the Designer stipulates on the Quality Sheet in the area considered for example :

ZONE IV Rz = Classe 2 where Rz = rim zone
Cz = Classe 4 Cz = core zone see fig. 5 (page 57)

Table 3
Threshold for notation

Class	AMPLITUDE							
	Notation threshold				Area of consideration			
	DAC Method	AVG Method	Back wall echo attenuation		DAC Method	AVG Method	Back wall echo attenuation (3)	
	$\frac{D}{R} \geq$	\emptyset equivalent (mm) \geq	$\frac{\Delta F}{F_0} \geq$	% \geq	$\frac{D}{R} \geq$	\emptyset equivalent (mm) \geq	$\frac{\Delta F}{F_0} \geq$	% \geq
1 (5)	0,15	2	0,25	25	0,25	3	0,25	25
2 (5)	0,25	3	0,25	25	0,50	4	0,25	25
3	0,25	3	0,5	50	1	6	0,5	50
4	0,5	4	0,5	50	1,8	8	0,5	50
5	0,5	4	0,5	50	3	10	0,75	75
6	0,5	4	0,5	50	4	12	0,75	75

() See page 56

Table 4

NUMBER OF LOCALIZED INDICATIONS (2) (indications not measurable in surface)

Maximum acceptable density per dm² based on the area
considered defined in Table 3 (4)

Class	DEPTH INVESTIGATION OR THICKNESS OF THE STEEL CASTING IN THE CONTROLLED AREA (mm)				Acceptable distance between 2 indications \geq mm
	≤ 50	$> 50 \text{ à } 100$	$> 100 \text{ à } 250$	$> 250 \text{ à } 600$	
1 (5)			not acceptable		12
2 (5)					
3	3	4	5	6	10
4					
5					
6					8

() See page 56

Table 5

MESURABLE INDICATIONS IN SURFACE ⁽⁶⁾

Limits of acceptance based on the area considered defined in Table 3 ⁽⁴⁾

DEPTH OF INVESTIGATION OR THICKNESS OF THE STEEL CASTING IN THE AREA INSPECTED

Class	≤ 50 mm			> 50 to 100 mm			> 100 to 250 mm			> 250 to 600 mm		
	Individual S Surface (cm ²)	Individual S cumulated Surface (cm ²)	Extension in depth % (8)	Individual S Surface (cm ²)	Individual S cumulated Surface (cm ²)	Extension in depth % (8)	Individual S Surface (cm ²)	Individual S cumulated Surface (cm ²)	Extension in depth % (8)	Individual S Surface (cm ²)	Individual S cumulated Surface (cm ²)	Extension in depth % (8)
1 ⁽⁵⁾	Avg Method Ø equivalent to < 3 mm or DAC Method D/R < 0,25									non acceptable		
2 ⁽⁵⁾	1	5	2	2	15	5						
3	2	25	10	3	35	10	15	100	10	40	200	10
4	8	50	15	12	100	15	25	150	15	60	300	15
5	15	100	20	25	150	20	40	200	20	100	350	20
6	20	200	20	30	250	20	50	300	20	200	400	20

() See page 56

LEGEND for tables 3, 4 and 5

- (1) Cracks are unacceptable.
- (2) When the dimension of the indication is smaller than the diameter of the ultrasonic beam, it is recommended to use an SE probe (separate transmitter receiver) or a probe whose limit of the near field is \leq than the distance in depth of the defect.
- (3) The indications with a diminishing back wall echo of $> 50\%$ and/or with an attenuation of the back wall echo without the appearance of defect echo in the area of consideration and of surface superior to that indicated in Table 5, will be the subject of further investigations (see § 1.8 Indications to be confirmed).
- (4) Any accumulation of amplitude indications included between the threshold of notation and the area of consideration must be considered as an indication «to be confirmed» see § 1.8.
Acceptability of repair decisions will be taken on a case by case basis.
Isolated indications which seem to originate from several defects located at different depths will be considered as multiple indications.
- (5) Classes 1 and 2 are reserved for exceptional requirements determined by the Designer.
The inspection will be made using a probe with a separate transmitter receiver (of 4 MHz wherever possible) for thicknesses or depths ≤ 50 mm. Beyond those thicknesses or depths, use a standard perpendicular probe with a silence zone (dead zone) as short as possible.
- (6) The dimension of the indication is greater than the diameter of the ultrasonic beam.
The range is determined according to the - 6 dB method (see § 1.6.2.3).
- (7) It is the limit of acceptance of the sum of the elementary S surfaces, of the indications noted on an examined surface of 1000 cm² (approx. 32 x 32 cm).
- (8) The maximum acceptable extension in depth of the indication is expressed in % of the examined thickness (see figure 4).
- (9) Figure 5 indicates the distribution of areas in the thickness of a part.

Rz = Superficial areas (rim zone)

They are equal to 1/3 of the thickness of the part in its delivery condition with a maximum of 30 mm

Cz = Median area (core zone)

It is the area included between the two previous areas.

Note :

The demarcation between superficial and median areas is not always clearly defined when the casting is of complex shape. When discontinuities are located at the limits of these areas, consultation between the Designer and the Founder or Manufacturer is necessary.

Figure 4 :

Measure of the depth extension of the defect
using a perpendicular probe

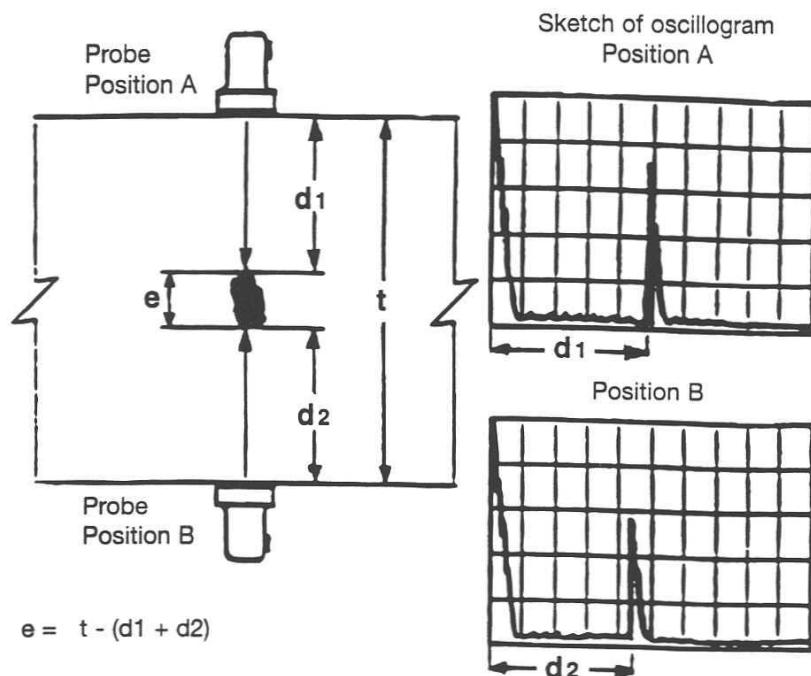
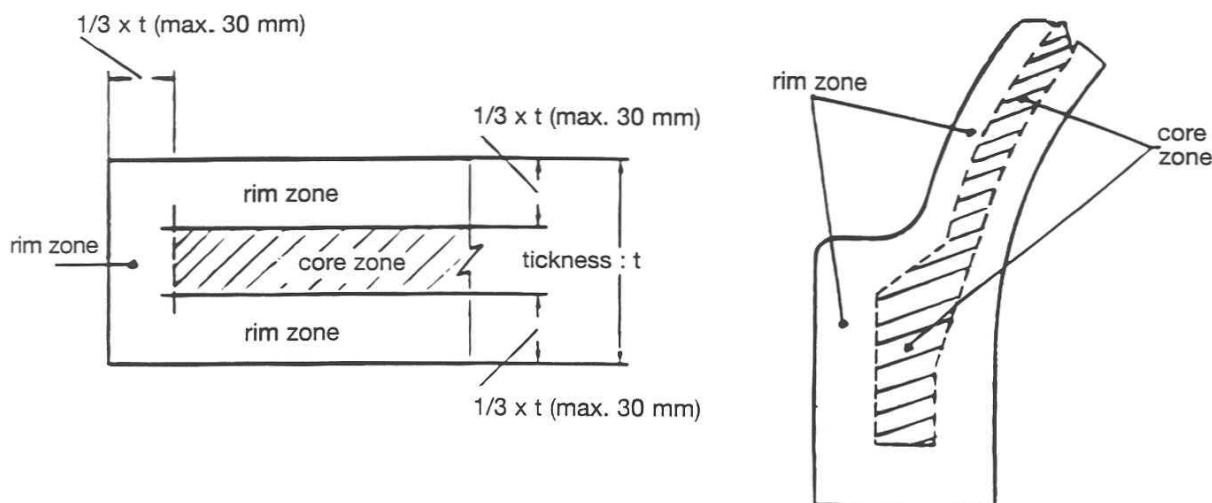


Figure 5 : Distribution of areas in the thickness of a part



1.8 INDICATIONS «TO BE CONFIRMED»

The indications «to be confirmed» will be the subject of additional investigations by using for example different types of probes so as to confirm or contradict the existence of a discontinuity and to indicate as much as possible the nature and the dimensions (see Part 2 - Inspection of transverse waves).

The Designer will decide, taking into consideration the degree of solicitation of the area in question as well as the possible evolution of the defect under service conditions.

If the Designer so requires, a detailed report with sketch will be established and transmitted to him.

If necessary and if the casting allows such inspection, confirmative radiographic inspection may be required, provided that the inspection criteria had been defined on the Quality Sheet when the order was placed. These criteria only apply to «indications to be confirmed» according to the present specification.

1.9 INSPECTION OF WELDED AREA (REPAIRS)

Unless otherwise agreed upon by the Designer, Founder and/or Manufacturer, repairs by welding will be inspected under the same conditions as those defined by the examination before repair.

However, the Designer may recommend that any «major» repairs be inspected as much as possible, so that repairs by welding be inspected using transverse wave probes (see Part 2 of the specification).

The methods of these supplementary inspections will be indicated on the Quality Sheet or in the Designer's Specification (areas to be inspected, methods used, criteria of acceptance) ◆

Definition of repairs considered «major» see chapter GE 70-3 § 5.1.2..

1.10 INSPECTION REPORT

The inspection report must indicate :

- Identification of the Founder or the Manufacturer or the Designer.
- Identification of the casting (heat number, traceability).
- Steel grade of casting.
- Designation of examination of documents used: reference to the present specification, Quality Sheet ...
- Stage of manufacture at inspection
- Mode of surface preparation.
- Trademark and type of apparatus and probe used.
- Conditions of calibration and adjustment.
- Areas inspected.
- Characteristics (position, amplitude, surface) of the indication \geq the notation threshold.
- Inspection results.
- Name of the inspector, his signature and his certification.
- Identification of the firm in charge of the inspection, if sub-contracted.
- Date of inspection and signature of the responsible person for inspection.

PART 2

TRANSVERSE WAVES EXAMINATION

2.1 OBJECTIVE AND FIELD OF APPLICATION

This specification is applicable, after an agreement between the Designer, the Founder or the Manufacturer, for carrying out complementary investigations, for the characterization of indications, for inspection of weld ends, for the examination of welds, or of areas repaired by welding, for the inspection of welded joints between two parts. It defines the procedure to implement for ultrasonic inspection of ferritic or martensitic steel of more than 12 mm in thickness. It applies to the pulse echo method using transverse waves (angle probe).

2.2 METHODS USED

The methods described in this specification involve :

- either the plotting of a «Distance Amplitude Curve» (DAC) from the reflection of transverse waves obtained on the generator of holes drilled parallel to the contact surface,
- or using existing reference diagrams (AVG method).

The choice of either method for the part as a whole will be specified in the Quality Sheet.

The angle probe is shifted manually over the surface of the part to be examined. Internal discontinuities causing an echo are analysed (dimensions, amplitude, position, nature of defect).

2.3 ULTRASONIC INSPECTION MATERIAL

2.3.1 APPARATUS

The apparatus is identical to the one used in longitudinal waves (see § 1.3.1).

2.3.2 PROBES

Transverse wave probes: The recommended refraction angles are 45°, 60° and 70°, the frequency used will generally be included between 2 and 5 MHz

2.3.3 OPERATION TO PERFORM DAILY ON THE APPARATUS AND EVERY CHANGE OF SHIFT :

- Verification of physical condition and external appearance of the apparatus (pulse generator, probe, cable).
- Quick verification of the calibrated amplifier.
- Verification of the direction of the beam in the vertical median plane of the probe (maximum squint angle 2°).
- Verification of the emergency point and the angle of refraction of the probe.
- Verification of the resolution power.

The depth resolution must be assessed for the whole apparatus (apparatus / cable / probe) through the measure of the width of the echo obtained on the basic quarter round of the steel calibration block IIW A2. The time base is adjusted on 50 mm full scale in the transverse waves. Knowing that 91 mm of steel permeated by longitudinal waves correspond to 50 mm of steel permeated by transverse waves, the apparatus is adjusted by placing a perpendicular probe on the 91 mm thick calibration block as per figure 6 position A. The perpendicular probe is replaced by the angle probe to analyse. It is placed on the calibration block as per figure 6 position B.

By adjusting the shift, one can see in the middle of the screen, the echo obtained on the calibration block quarter round (without changing scale).

The amplitude of the echo must be adjusted from 80 to 100% of the total height of the screen and the width of the screen must be measured in millimetres of steel at a value of 10% of the height of the echo.

Table 6 shows characteristic values.

Figure 6 : Verification of the resolution power

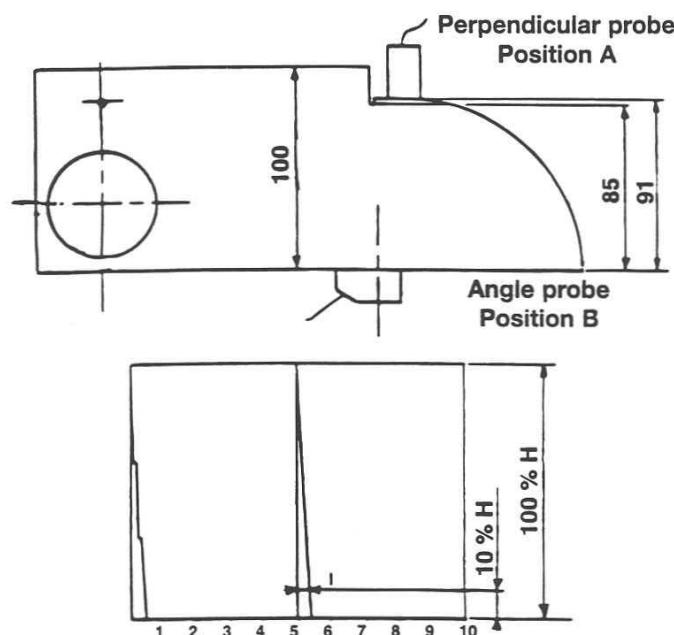


Table 6

Frequency MHz	Width of the echo Transverse waves mm
1	-
2 or 2,25(*)	5
4	3
5	2,5

(*) Frequency recommended

2.3.4 COUPLANT

The couplant used is identical to that used in longitudinal waves (see § 1.3.4).

2.3.5 REFERENCE BLOCKS (DAC)

The reference blocks are used to establish the Distance Amplitude Curve (DAC).

They are produced in a steel casting presenting acoustic characteristics as close as possible to the blocks used in longitudinal waves.

Under all circumstances, the attenuation difference of the ultrasound signal between the reference block and the part to be inspected will be verified (see § 2.4.5.1). The reflectors are made of holes drilled laterally at equal depths respectively at 1/4, 1/2 and 3/4 of the thickness of the reference block. The reference block dimensions will be produced in conformity with ASTM A 609, figure 4 and as indicated in table 7.

Table 7
Caracteristics of the reference blocks in relation to thickness

Thickness to inspect «t» or depth of the excavation mm	CARACTERISTICS OF THE REFERENCE BLOCKS			
	N°	Thickness «T» of the block mm	Location of holes	Diameter of the holes ± 0,05 mm
< 25	1	25 or t	1/2 T	2,4
> 25 to 50	2	50 or t	1/4 T - 1/2 T - 3/4 T	3
> 50 to 100	3	100 or t	1/4 T - 1/2 T - 3/4 T	5
> 100 to 150	4	150 or t	1/4 T - 1/2 T - 3/4 T	6
> 150 to 200	5	200 or t	1/4 T - 1/2 T - 3/4 T	8
>200 to 250	6	250 or t	1/4 T - 1/2 T - 3/4 T	10
> 250	7	t	1/4 T - 1/2 T - 3/4 T	(*)

(*) Above 250 mm, for each segment of 50 mm, increase the Ø of the hole by 1.6 mm.

Other types of reference blocks can be used.

These blocks shaped like a parallelepipedon have a series of cylindrical holes drilled from one end to the other, subject to the width of the reference block, parallel to the surface to be explored.

The diameter of these holes is a function of the thickness to be inspected (as per table 7).

- For a diameter equal to or less than 5 mm, the first hole will be drilled at 10 mm from the surface to be explored. The difference in depth between the next holes is of 20 mm.
- For a diameter greater than 5 mm, the first hole is drilled at 20 mm from the surface to explore. The difference in depth between the next holes is 40 mm.

Each block must be permanently identified on its side using its reference identification and its grade of steel.

2.3.6 REFERENCE DIAGRAM (AVG)

The AVG method is similar to the DAC method in so far as its objectives are concerned but it doesn't need any artificial reflectors for plotting. The reference diagrams proposed by the manufacturer for each type of probe is used (respectively electronic curves on digital equipment).

In the AVG diagrams, the relation between the length of the path of the sound waves and the amplification on the generating line of the circular section reflector, located perpendicular to the sound beam, is indicated as a parameter.

To determine the sensitivity of testing, the diameter of the circular section reference reflector is used, based on the thickness of the material to be tested.

Table 8
Circular section reference reflector \varnothing , in relation to thickness or depth

Thickness to control «b» or depth excavation mm	Circular section reference reflector Diameter in mm
≤ 25	2
> 25 to 50	2,5
> 50 to 100	3
> 100 to 150	4
> 150 to 200	5
> 200 to 250	5
> 250 to 300	6
> 300 to 400	7
> 400 to 500	8

2.4 INSPECTION CONDITIONS

2.4.1 STAGE OF INSPECTION

The ultrasonic inspection will always be performed after quality heat treatment, in case of inspection of repairs or construction welds, the inspection will be performed after the final heat treatment.

2.4.2 AREAS TO BE INSPECTED

The areas subjected to inspection and their range will be defined on the Quality Sheet if need be, subject to the following limitations. ♦

2.4.2.1 Welded joints or repairs

The area subjected to inspection should include the welding and the area adjacent to it, based on the three examples in figures 7, 8 and 9.

Figure 7 : Full penetration weld between two parts

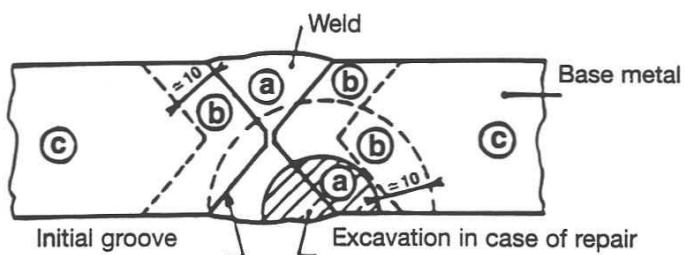
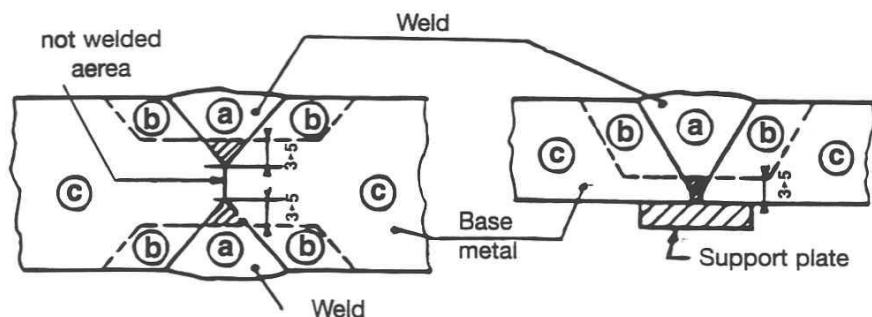


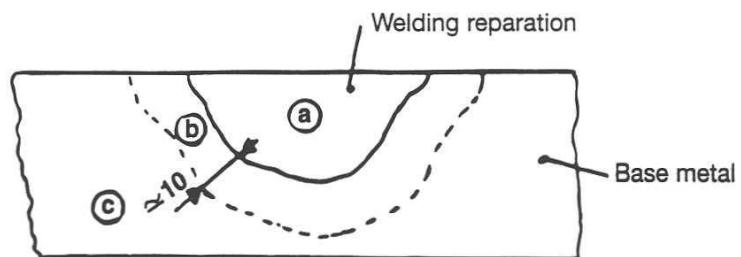
Figure 8 : Partial penetration weld or weld on supporting plate



Note for figures 7 and 8:

The hatched lined areas correspond to the area of doubt in view of the limits of the method.

Figure 9 : Weld reparation



Legend :

Areas a + b : Application of welding acceptance criteria
Area c : Application of base metal acceptance criteria

2.4.2.2 Examples of pending welds or areas to be welded

The area subjected to inspection generally includes a 20 mm space relative to the edge of the groove (example figure 10) or to the area to be welded (example figure 11).

Figure 10 : Pending weld
groove

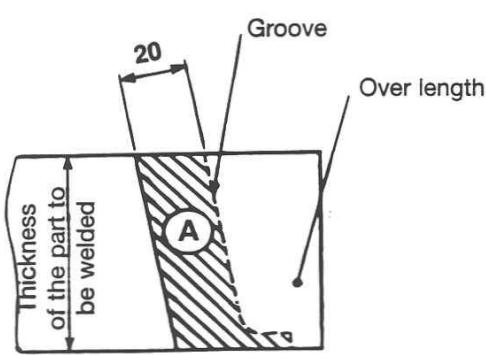
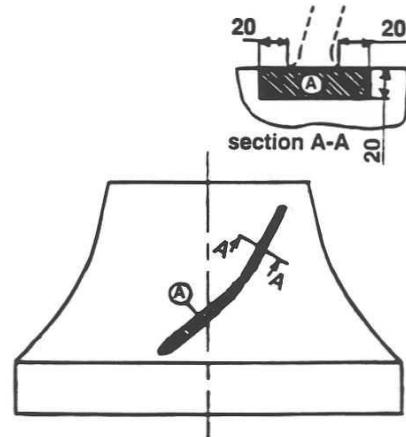


Figure 11 : Hub area to be welded



The extent of the inspection includes 100% of the volume of area A

2.4.3 SURFACE PREPARATION

The exploration surfaces must be free of any deposit, product, asperities which could hinder the transmission of waves or the free movement of the probe or which could provoke errors of interpretation (parasitic echoes). In cases of repair, the welds will be ground fine or machined. Unless otherwise specified, roughness Ra will not exceed 6.3 µm.

2.4.4 ADJUSTMENT OF THE SPEED OF SWEEP

The sweep range may be calibrated:

- either in distance over which to sweep,
- or in real depth of reflectors.

2.4.4.1 Adjustment of the distance swept

The adjustment is made using the fundamental steel calibration block IIW A2.

2.4.4.2 Adjustment of real depth of reflector

The adjustment is made from the artificial reflectors of the reference block indicated in § 2.3.5.

The relative position of an echo on the screen allows to determine the real depth of the corresponding reflector.

2.4.5 ADJUSTMENT OF THE AMPLIFICATION AND THE INTENSITY

2.4.5.1 Use of reference block defined in § 2.3.5 (DAC method)

The adjustment of the amplification and the intensity is carried out from indications obtained from artificial reflectors (cylindrical holes in the reference blocks).

These adjustments are carried out simultaneously, the amplification threshold being brought back to the minimum. During these adjustments, the intensity must be maintained as low as possible.

The height adjustment of the reference echoes is obtained through the adjustment of the amplification.

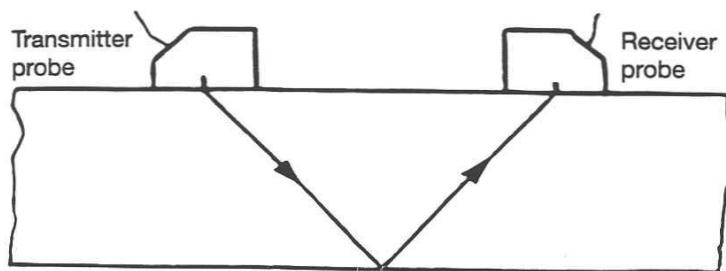
Correction for ultrasonic energy absorption

To consider to a certain extent possible differences in surface finish and/or absorption of ultrasonic waves between the casting under inspection and the reference block, the amplification will be modified as follows:

- Place the probe in an area of the casting which has parallel surfaces and whose thickness is equivalent to that of the block and whose surface finish and preferably whose internal structure is representative of the rest of the casting. This correction is made from the comparison of attenuations in the block and in the part over the same path of the ultrasonic beam, with the help of a transverse wave probe of the same type (dimensions and frequency) as those used for inspecting the part.

- Place two probes, one a transmitter and the other a receiver over the reference block as per figure 12. Note the gain necessary to bring the reception signal to an amplitude equal to 80% of the height of the screen. Without modifying the adjustments, the two probes are then placed over the part to be inspected. The difference in gain g_1 is translated by the increase in the gain necessary for the correction of ultrasonic energy absorption. The gain to use during the examination corresponds to the gain used to plot the distance amplitude curve plus the gain g_1 . In practice this correction is carried out only if $g_1 > 2\text{dB}$.

Figure 12 : Correction for ultrasonic energy absorption



Adjustment from indications obtained from artificial reflectors on the reference block

Two methods of adjustment may be used :

a) Distance amplitude curve (DAC)

The principle to plot the distance amplitude curve is identical to that described for longitudinal waves (see paragraph 1.4.5.1 a)

The maximum amplitude of the echoes obtained on cylindrical holes located at $1/4 T$ and $1/2 T$ from the same surface sounding and $3/4 T$ on the opposite surface is noted.

The curve linking these different points constitutes the distance amplitude curve. A fractioned distance amplitude curve is established when the amplitude of the echo obtained is less than 20% of the screen height. The same adjustment may be obtained using other types of reference blocks as described in paragraph 2.3.5.

b) When the apparatus so allows, the **adjustment of the sensitivity** is performed by taking note of the **amplitude values necessary** to bring the amplitude of the echoes on each reflector at the same height (approximately 80% of the height of the screen).

2.4.5.2 Use of existing reference diagrams defined in paragraph 2.3.6 (AVG method)

The method is identical to that of longitudinal waves (see § 1.4.5.2)

The acoustic absorption attributable to the material shouldn't be neglected and the method of correction of transfer described for the DAC method is applicable.

2.4.6 FREQUENCY OF VERIFICATION OF THE ADJUSTMENTS

The frequency of verification of the adjustments is identical to that defined in longitudinal waves (see § 1.4.6).

2.5 METHOD OF SURCHING FOR DEFECTS

The method should allow the investigation of the whole area to be inspected. The refraction angle of the ultrasonic beam is included between 70° and 45° . It will be a function of the thickness to be inspected, of the geometric shape of the casting or welded joint and of the type of indications to be determined.

The sweeping method over the area to inspect, the speed of shifting of the probe as well as sensitivity to the defects are identical to those defined for longitudinal waves (see § 1.5).

INDICATIONS TO BE INVESTIGATED.

2.5.1 EXAMPLE OF A WELDED JOINT BETWEEN TWO PARTS OR AN AREA REPAIRED BY WELDING

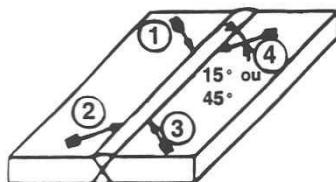
a) Detection of longitudinal indications

Longitudinal indications are those located in the same direction as the direction of welding. Two sounding angles with a difference of at least 10 to 15° between them shall be used.

b) Detection of transverse indications

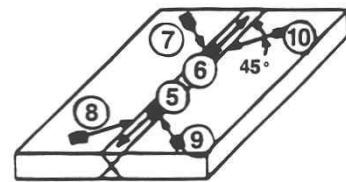
Transverse indications are those situated perpendicularly to the direction of welding. The indications will be detected in case of non machined welds with an angle of rotation of the probe relative to the direction of welding (see figure 13) and following two 180° directions for machined or ground welds (example figure 14).

Figure 13 : Non machined welds



Angle of rotation of the probe 15° or 45° in case of ESW*
(Exploration direction 1, 2, 3 and 4)

Figure 14 : Machined welds



2 directions at 180° relative to the probe (direction of exploration 5 and 6)
Note: In case of ESW*, the supplementary angle of rotation of the probe is 45° (supplementary exploration direction 7, 8, 9 and 10)

*ESW: Electroslag Welding

2.5.2 EXAMPLE OF PENDING WELDS, AREAS TO BE WELDED, INDICATIONS TO BE CONFIRMED OR COMPLEMENTARY INVESTIGATIONS.

In all the areas to be inspected, the operator must carry out a complete sweep in all directions in order to find indications producing an echo.

Different types of angle probes will be used to obtain the maximum amplitude of the indication.

2.6 CHARACTERIZATION OF THE INDICATIONS

2.6.1 LOCATION

The location of the indications is identical to that defined for longitudinal waves (see § 1.6.1).

2.6.2 DIMENSIONING OF ECHOES OBTAINED BY THE INDICATIONS

2.6.2.1 Dimensioning in amplitude from the distance amplitude curve (DAC) obtained on the cylindrical holes

The dimensioning in amplitude is identical to that defined for longitudinal waves (see § 1.6.2.1).

2.6.2.2 Dimensioning in amplitude by the AVG method

The dimensioning in amplitude is identical to that defined for longitudinal waves (see § 1.6.2.2).

2.6.2.3 Dimensioning

a) Example of indications that are measurable in surface

The outline or the length of the defect is defined by the - 6 dB method as described for longitudinal waves (see § 1.6.2.3)

b) Example of indications that are non measurable in surface

The use of graph figure 4 of Euronorm CEN/TC 1 90 N 224: 1993 located in § 1.6.2.3 should be helpful.

2.6.3 CUMULATION OF INDICATIONS

a) Example of indications measurable in surface

The cumulation of two similar indications is identical to that defined for the longitudinal waves (see § 1.6.4).

b) Examples of indications whose length may be measured (cracks, lack of fusion ...)

• Single indication

Two indications seen through two different soundings (different angles or orientations) are considered obtained from the same reflector if the two following conditions are met :

- The distance separating the middle of their projections on the surface explored is less than 10% of the maximum depth.
- The distance between the middle of their projections over a cross section of the weld is 10% lower than the maximum depth

In these cases, the indication noted is characterized by the weakest depth and the most significant dimensions and amplitudes.

- **Separate indications**

Separate indications are cumulative if both of the following conditions exist :

- The distance which separates their projections on the surface explored is equal to or less than six times the length of the smallest projection or 20 mm if one of them is not measurable.
- The distance separating their projections over a cross section of the weld is equal to or less than 20 mm.

The amplitude of the cumulated indication is that of the most significant of the separate indications. Its dimension is obtained by joining the farthest extremities of both indications.

The rule of cumulation can only be applied to indications taken in isolation.

2.7 ACCEPTANCE CRITERIA

2.7.1 EXAMPLE OF A WELDED JOINT BETWEEN TWO PARTS OR AN AREA REPAIRED BY WELDING

The acceptance criteria are related to the characteristic of the defect, the height of the defect echo or the equivalent AVG diameter, their individual length and their cumulative length.

- Must be noted all the indications, the echo amplitude of which is $\geq 50\%$ of the amplitude of the reference echo.
- The indications producing an echo 20% superior to the reference echo will be analysed to determine their shape, their nature, their position and to assess them based on the following criteria :

a) Non volume defects

Indications viewed as defects such as cracks, lack of fusion, incomplete penetration are considered unacceptable regardless of their length or amplitude.

b) Volume defects

Defects are unacceptable if their amplitude exceeds the reference level and if their length exceeds the following dimensions:

Length = 6 mm per $t \leq 19$ mm

Length = $t/3$ for t included between 10 and 57 mm

Length = 19 mm for $t > 57$ mm

t is the thickness of the weld or the depth of excavation.

For welds joining 2 elements of different thicknesses « t » is the smallest of the two thicknesses.

2.7.2 EXAMPLES OF PENDING WELDS, OF AREAS TO WELD OR OF COMPLEMENTARY INVESTIGATIONS

The acceptance criteria are based on the characterization of the defect, the height of the defect echo, the equivalent AVG diameter, the number of non measurable indications, the surface of each basic zone, the cumulated surface and length of the basic zones.

- All indications, the amplitude echo of which is $\geq 50\%$ of the reference echo must be noted.
- The indications producing an echo $> 20\%$ of the reference echo will be analysed to determine their shape, their nature, their position and to assess them, based on the following criteria :

a) Non volume defects

Linear discontinuities, hot cracks, shrinkage cavities are considered unacceptable regardless of their length and their amplitude.

b) Volume defects

Defects are unacceptable if their amplitude exceeds the reference level and if the number of non measurable indications or surface measurable indications, exceed respectively the set values in tables 4 and 5 defined in § 1.7 «CRITERIA OF ACCEPTANCE» for longitudinal waves.

Note :

This note is applicable to § 2.7.1 et 2.7.2 :

Indications below the notation threshold: Individual amplitude indications inferior to the notation threshold aren't considered as significant of defects requiring repair. However, at the Designer's request, they are the subject of additional analysis so as to determine their nature, if these defects are continuous or repetitive or if their position is critical.

2.8 INSPECTION REPORT

The inspection report must indicate the same informations as that defined in § 1.10 «Longitudinal waves examination».